



e-ISSN: 2319-8753 | p-ISSN: 2347-6710

# IJRSET

International Journal of Innovative Research in  
**SCIENCE | ENGINEERING | TECHNOLOGY**

# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 11, Issue 12, December 2022

**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA

Impact Factor: 8.118

9940 572 462

6381 907 438

[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# Review on Bio Remediation and Impact of Heavy Metal on Soil

Shiella Tikku, Neeta Kanoongor<sup>2</sup>, Vandana Mathur<sup>3</sup>, Anita Kothari<sup>4</sup>

Department of Chemistry, S.P.C. Government College, Ajmer, Rajasthan, India

**ABSTRACT:** Heavy metals and pesticides are at the top of the list of substances harmful to the environment. Toxic pollution is a critical environmental problem that poses a serious threat to human health and agricultural production. Bioremediation is an effective method for treating soil contaminated with heavy metals. This is a widely accepted method, mostly done in situ; therefore suitable for establishing/restoring crops in treated soils. Plants use different mechanisms for the biological remediation of contaminated soil. Using plants to treat contaminated soil is a more common approach in bioremediation of soil contaminated with heavy metals. The combination of microorganisms and plants is a bioremediation approach that allows for more effective cleaning of soil contaminated with heavy metals.

**KEYWORDS:** heavy metal, Bioremediation, soil, plants.

## I. INTRODUCTION

Heavy metals occur naturally in small quantities in the earth's crust; usually, heavy metals are stored by man-made and anthropogenic activities that increase their concentration in the soil. These metals are harmful to plants and animals. Some of these activities include metal mining and smelting, burning of fossil fuels, industrial manufacture of batteries and other metal products, use of chemical fertilizers, pesticides, untreated sewage sludge and municipal solid waste used in agriculture to produce crops. There are various methods for recovering soil contaminated with metals; they range from physical and chemical methods to biological methods. Most of the physical and chemical methods (such as encapsulation, compaction, stabilization, electrokinetics, steam extraction, and soil washing) are expensive and make the soil unsuitable for plant growth [1]. Biological approaches (bioremediation), on the other hand, promote plant establishment/restoration in contaminated soil. This is an ecological approach because it is achieved through natural processes. Bioremediation is also an economical remediation technique compared to other remediation techniques. This article discusses the nature and properties of soil contaminated with heavy metals. Plant growth and performance on these soils was studied. Biological approaches like using plants for remediation of heavy metal contaminated soils are also highlighted.

### Soil polluted by heavy metals

Soil properties affect metal availability in various ways. Harter [2] reported that soil pH is the main factor affecting the availability of metals in the soil. The availability of Cd and Zn in the roots of *Thlaspi caerulescens* decreased with increasing soil pH [3]. Organic matter and hydrated iron oxides have been shown to reduce the presence of heavy metals by immobilizing these metals [4].

Conversely, heavy metals can change soil properties, especially soil biological properties [5]. Monitoring changes in soil microbiological and biochemical properties after contamination can be used to assess the intensity of soil contamination, because this method is more sensitive and results can be obtained more quickly than monitoring soil physical and chemical properties [6].

### Bioremediation of heavy metal polluted soils

Bioremediation is the use of organisms (microorganisms and/or plants) to treat contaminated soil. It is a widely recognized method of soil remediation as it is thought to be a natural process. This is an equally inexpensive method of soil remediation. Blaylock et al. [7] reported savings of 50% to 65% when bioremediation was used to treat 1 hectare of Pb contaminated soil compared to conventional methods (excavation and disposal) for the same purpose. Although bioremediation is a non-destructive soil remediation method, it is generally time consuming and its use to treat soil contaminated with heavy metals is sometimes affected by the climatic and geological conditions of the site to be repaired [8].

Heavy metals cannot be decomposed during bioremediation, only converted from one organic complex or oxidation state to another. Due to changes in their oxidation state, heavy metals can be made less toxic, more volatile, water soluble (and therefore removable by washing) or less water soluble (allowing them to precipitate and become lighter). removed from the environment) or lack bioavailability [9, 10].

### Using Plants for Remediation of Heavy Metal Polluted Soils

Utilization of plants to remediate soil contaminated with heavy metals. Phytoremediation is an aspect of bioremediation that uses plants to treat contaminated soil. It is suitable when the pollutant covers a large area and is in the plant root zone [10]. Phytoremediation of soil contaminated with heavy metals can be achieved through different mechanisms.

These mechanisms include phytoextraction, phytostabilization, and phytovolatilization

**1. phytoextraction-** This is the most common form of phytoremediation. This causes accumulation of heavy metals in the roots and shoots of phytoremediation plants. These plants are then collected and burned. Plants used for phytoextraction generally have the following characteristics: fast growth, high biomass, extensive root system, and ability to tolerate large amounts of heavy metals. The ability to tolerate high concentrations of heavy metals in these plants can lead to accumulation of metals in the harvestable parts; this can be a problem due to contamination of the food chain [1]. Depending on the characteristics of the plants involved in the process, there are two approaches to phytoextraction. The first approach involves the use of natural hyperaccumulators, i.e. plants with a very high ability to accumulate metals, while the second approach involves the use of high biomass plants whose ability to accumulate metals is induced through the use of chelates, i.e. H. Improvement with metal mobilization capacity [11]. Hyperaccumulators accumulate 10 to 500 times more metals than normal plants [96]; therefore, they are very suitable for phytoremediation. An important property that allows hyperaccumulation is the tolerance of this plant to increased concentrations of this metal (hypertolerance). This may result from plant exclusion of these metals or from the compartmentalization of these metal ions; This means that the metal is trapped in the vacuolar compartment or cell wall and hence cannot reach the cellular sites where vital functions such as respiration and cell division take place [10, 12]. In general, a plant can be called a hyperaccumulator if it meets the following criteria: (i) The concentration of metals in shoots must be higher than 0.1% for Al, As, Co, Cr, Cu, Ni and Se, higher than 0.01% for Cd and more than 1.0% for Zn [13]; ii) the ratio of shoot to root concentrations must be consistently greater than 1 [14]; this shows the ability to transport metals from roots to shoots and the ability of hypertolerance [1]; iii) shoot-to-root concentration ratio must be higher than 1; it indicates the level of plant metal uptake [1, 15]. Reeves and Baker [16] reported several examples of plants that are capable of accumulating large amounts of heavy metals and can therefore be used in remediation studies. *Pteris vittata* is an example of a hyperaccumulator that can be used to remediate As-contaminated soil [17]. Some plants have the ability to accumulate more than one metal. The possibility of contaminating the food chain through the use of hyperaccumulators is a major limitation of phytoextraction. However, many Brassicaceae species known as heavy metal hyperaccumulators contain large amounts of thiocyanate, making them inedible to animals; This reduces the availability of these metals in the food chain [18]. The addition of chelating agents prevents precipitation and absorption of metals by forming metal chelating complexes; this further enhances the bioavailability of these metals [1]. In addition, adding Chelates to the soil can transport more metals to the soil solution by dissolving precipitated compounds and removing adsorbed species [19]. Some chelates are also able to translocate heavy metals in plant shoots [20]. Marques et al. [1] Documented examples of synthetic chelates being used successfully to extract heavy metals from contaminated soils. Some of these chelates include EDTA (ethylenediaminetetraacetic acid), EDDS (SS-ethylenediaminedisuccinic acid), CDTA (trans-1,2-diaminocyclohexane-N,N,N<sub>p</sub>,N<sub>p</sub>-tetraacetic acid), EDDHA (ethylenediamine-di-o-hydroxyphenylacetic acid), DTPA (diethylenediaminepentaacetic acid) and HEDTA (N-hydroxyethylenediaminetriacetic acid). The main disadvantage of using chelates in phytoextraction is the potential for groundwater contamination from the extraction of these heavy metals [21].

**2. phytostabilization-** Phytostabilization involves using plants to immobilize metals, reducing their bioavailability through erosion and leaching. It is mostly used when phytoextraction is undesirable or even possible [15]. Marques et al. [1] argued that this form of phytoremediation is best applied when the soil is so heavily contaminated that using plants to extract metals would be time-consuming and therefore insufficient. On the other hand, Jadia and Fulekar [22] showed that plant growth (used for phytostabilization) is negatively affected when heavy metal concentrations in soil are high. Phytostabilization of heavy metals occurs through precipitation, absorption, reduction of metal valence or complex formation [23]. The effectiveness of phytostabilization depends on the plants used and soil amendments. Plants help stabilize the soil through their root system; thus they prevent erosion. Plant root systems also prevent

leaching by reducing seepage of water through the soil. In addition, plants prevent direct human contact with contaminants and equally provide surfaces for metal deposition and absorption [24]. Based on the above factors, it is important to select suitable plants for heavy metal phytostabilization. Plants used for phytostabilization should have the following characteristics: tight root system, ability to tolerate soil conditions, ease of cultivation and care in outdoor conditions, rapid growth to provide adequate ground cover, longevity, and ability to reproduce alone. Soil amendments used in phytostabilization help deactivate heavy metals; thus, they prevent plant metal uptake and reduce biological activity [1]. Organic materials are widely used as soil additives in phytostabilization. Marques et al. [25] showed that percolation of Zn through soil decreased by 80% after manure or compost was applied to contaminated soil where *Solanum nigrum* was grown. Other supplements that can be used for phytostabilization include phosphate, lime, biosolids and bedding [26]. The best soil amendments are those that are easy to use, safe for the workers who apply them, easy to make and inexpensive, and most importantly, non-toxic to plants [25]. In general, phytostabilization is very useful when rapid heavy metal immobilization is required to prevent groundwater contamination. However, because the pollutants remain in the ground, constant environmental monitoring is required, which can become problematic.

**3. phytovolatilization.** In this form of phytoremediation, plants are used to absorb pollutants from the soil; these pollutants are converted into volatile forms and then released into the atmosphere [27]. Phytovolatilization is widely used to remediate Hg contaminated soil. The toxic form of Hg (mercury ion) is converted to a less toxic form (elemental Hg). The problem with this process is that the newly formed product, namely elemental Hg, can be deposited back in lakes and rivers after being recycled through deposition; this in turn repeats the process of methyl-Hg production by anaerobic bacteria [27]. Raskin and Ensley [28] reported a lack of plant species with Hg hyperaccumulation properties. For this reason, genetically modified plants are usually used in phytovolatilization. Phytovolatilization can also be used to remediate Se-contaminated soil [1]. It involves the assimilation of inorganic Se to organic selenoamino acids (selenocysteine and selenomethionine). Selenomethionine is further biomethylated to dimethylselenide, which is lost by evaporation to the atmosphere [29].

### III. CONCLUSION

Plants growing on soil contaminated with heavy metals show decreased growth due to changes in their physiological and biochemical activities. This is especially true when the heavy metals involved do not play a beneficial role in plant growth and development. Bioremediation can be used effectively to treat soil contaminated with heavy metals. It is most suitable when the improved site is to be used for crop production as it is a non-destructive soil improvement method. Using plants for bioremediation (phytoremediation) is a more common approach for heavy metal bioremediation than using microorganisms. Plants use different mechanisms to restore soil contaminated with heavy metals. Phytoextraction is the most common method of phytoremediation to treat soil contaminated with heavy metals. Ensures complete elimination of contamination.

### REFERENCES

- [1] A. P. G. C. Marques, A. O. S. S. Rangel, and P. M. L. Castro, "Remediation of heavy metal contaminated soils: phytoremediation as a potentially promising clean-up technology," *Critical Reviews in Environmental Science and Technology*, vol. 39, no. 8, pp. 622–654, 2009.
- [2] R. D. Harter, "Effect of soil pH on adsorption of lead, copper, zinc, and nickel," *Soil Science Society of America Journal*, vol. 47, no. 1, pp. 47–51, 1983.
- [3] A. S. Wang, J. S. Angle, R. L. Chaney, T. A. Delorme, and R. D. Reeves, "Soil pH effects on uptake of Cd and Zn by *Thlaspi caerulescens*," *Plant and Soil*, vol. 281, no. 1-2, pp. 325–337, 2006.
- [4] L. Yi, Y. Hong, D. Wang, and Y. Zhu, "Determination of free heavy metal ion concentrations in soils around a cadmium rich zinc deposit," *Geochemical Journal*, vol. 41, no. 4, pp. 235–240, 2007.
- [5] M. Friedlova, "The influence of heavy metals on soil biological and chemical properties," *Soil and Water Research*, vol. 5, no. 1, pp. 21–27, 2010.
- [6] P. Nannipieri, L. Badalucco, L. Landi, and G. Pietramellara, "Measurement in assessing the risk of chemicals to the soil ecosystem," in *Ecotoxicology: Responses, Biomarkers and Risk Assessment*, J. T. Zelikoff, Ed., pp. 507–534, OECD Workshop, SOS Publ., Fair Haven, NY, USA, 1997.
- [7] M. J. Blaylock, D. E. Salt, S. Dushenkov et al., "Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents," *Environmental Science and Technology*, vol. 31, no. 3, pp. 860–865, 1997.

- [8] M. E. V. Schmöger, M. Oven, and E. Grill, "Detoxification of arsenic by phytochelatins in plants," *Plant Physiology*, vol. 122, no. 3, pp. 793–801, 2000.
- [9] C. Garbisu and I. Alkorta, "Bioremediation: principles and future," *Journal of Clean Technology, Environmental Toxicology and Occupational Medicine*, vol. 6, no. 4, pp. 351–366, 1997.
- [10] C. Garbisu and I. Alkorta, "Basic concepts on heavy metal soil bioremediation," *The European Journal of Mineral Processing and Environmental Protection*, vol. 3, no. 1, pp. 58–66, 2003.
- [11] D. E. Salt, R. D. Smith, and I. Raskin, "Phytoremediation," *Annual Review of Plant Biology*, vol. 49, pp. 643–668, 1998.
- [12] R. L. Chaney, M. Malik, Y. M. Li et al., "Phytoremediation of soil metals," *Current Opinion in Biotechnology*, vol. 8, no. 3, pp. 279–284, 1997.
- [13] R. L. Chaney, M. Malik, Y. M. Li et al., "Phytoremediation of soil metals," *Current Opinion in Biotechnology*, vol. 8, no. 3, pp. 279–284, 1997.
- [14] A. J. M. Baker and R. R. Brooks, "Terrestrial higher plants which hyperaccumulate metallic elements: a review of their distribution, ecology and phytochemistry," *Biorecovery*, vol. 1, pp. 81–126, 1989.
- [15] S. P. McGrath and F. Zhao, "Phytoextraction of metals and metalloids from contaminated soils," *Current Opinion in Biotechnology*, vol. 14, no. 3, pp. 277–282, 2003.
- [16] R. D. Reeves and A. J. M. Baker, "Metal-accumulating plants," in *Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment*, I. Raskin and B. D. Ensley, Eds., pp. 193–229, Wiley, New York, NY, USA, 2000.
- [17] L. Q. Ma, K. M. Komar, C. Tu, W. Zhang, Y. Cai, and E. D. Kenelley, "A fern that hyperaccumulates arsenic—a hardy, versatile, fast-growing plant helps to remove arsenic from contaminated soils," *Nature*, vol. 409, p. 579, 2001.
- [18] F. Navari-Izzo and M. F. Quartacci, "Phytoremediation of metals," *Minerva Biotecnologica*, vol. 13, no. 2, pp. 73–83, 2001.
- [19] W. A. Norvell, "Comparison of chelating agents as extractants for metals in diverse soil materials," *Soil Science Society of America Journal*, vol. 48, no. 6, pp. 1285–1292, 1984.
- [20] M. J. Blaylock, D. E. Salt, S. Dushenkov et al., "Enhanced accumulation of Pb in Indian mustard by soil-applied chelating agents," *Environmental Science and Technology*, vol. 31, no. 3, pp. 860–865, 1997.
- [21] E. Lombi, F. J. Zhao, S. J. Dunham, and S. P. McGrath, "Phytoremediation of heavy metal-contaminated soils: Natural hyperaccumulation versus chemically enhanced phytoextraction," *Journal of Environmental Quality*, vol. 30, no. 6, pp. 1919–1926, 2001.
- [22] C. D. Jadia and M. H. Fulekar, "Phytotoxicity and remediation of heavy metals by fibrous root grass (sorghum)," *Journal of Applied Biosciences*, vol. 10, pp. 491–499, 2008.
- [23] C. D. Jadia and M. H. Fulekar, "Phytoremediation of heavy metals: recent techniques," *African Journal of Biotechnology*, vol. 8, no. 6, pp. 921–928, 2009.
- [24] V. Laperche, S. J. Traina, P. Gaddam, and T. J. Logan, "Effect of apatite amendments on plant uptake of lead from contaminated soil," *Environmental Science and Technology*, vol. 30, no. 10, pp. 1540–1552, 1997.
- [25] A. P. G. C. Marques, R. S. Oliveira, A. O. S. S. Rangel, and P. M. L. Castro, "Application of manure and compost to contaminated soils and its effect on zinc accumulation by *Solanum nigrum* inoculated with arbuscular mycorrhizal fungi," *Environmental Pollution*, vol. 151, no. 3, pp. 608–620, 2008.
- [26] D. C. Adriano, W. W. Wenzel, J. Vangronsveld, and N. S. Bolan, "Role of assisted natural remediation in environmental cleanup," *Geoderma*, vol. 122, no. 2–4, pp. 121–142, 2004.
- [27] United States Environmental Protection Agency, *Electrokinetic and Phytoremediation In Situ Treatment of Metal-Contaminated Soil: State-of-the-Practice*, EPA/542/R-00/XXX, Environmental Protection Agency, Office of Solid Waste and Emergency Response Technology Innovation Office, Washington, DC, USA, 2000.
- [28] I. Raskin and B. D. Ensley, *Phytoremediation of Toxic Metals: Using Plants to Clean Up the Environment*, John Wiley & Sons, New York, NY, USA, 2000.
- [29] N. Terry, A. M. Zayed, M. P. de Souza, and A. S. Tarun, "Selenium in higher plants," *Annual Review of Plant Biology*, vol. 51, pp. 401–432, 2000.



**INNO SPACE**  
SJIF Scientific Journal Impact Factor  
**Impact Factor: 8.118**



**ISSN** INTERNATIONAL  
STANDARD  
SERIAL  
NUMBER  
INDIA



# INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

 **9940 572 462**  **6381 907 438**  **ijirset@gmail.com**



[www.ijirset.com](http://www.ijirset.com)

Scan to save the contact details